The Proposed DESDynI Array-Fed Reflector Feed

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***Abstract*—This paper describes the feed antenna for a proposed NASA Earth orbiting radar sensor currently in formulation at the Jet Propulsion Laboratory (JPL). The proposed array-fed reflector antenna architecture would enable large physical aperture imaging from space at relatively low cost and high technology readiness. Design, construction, and modeling of the feed antenna are described.**

I. Introduction and Background

The Deformation Ecosystem Structure and Dynamics of Ice (DESDynI) mission concept is being developed by NASA for Earth-orbit remote sensing. The proposed mission, envisioned as an interferometric synthetic aperture radar operating at L-band, would be enabled by a new mode of radar imaging known as SweepSAR, as well as a large-aperture antenna comprising a deployable reflector antenna fed by an active switched array of patch elements [1]. This paper focuses on the design of the passive feed array for large-aperture antenna.

JPL has been involved in a number of Planetary and Earth Science synthetic aperture radar (SAR) missions over the last four decades, including the successful deployment of the Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) instrument in 2005. Over the last decade, JPL has been studying options to develop the next generation of orbiting SAR sensors for Earth Science. A driving requirement among these studies is to operate fully polarimetrically at L-band with a short orbital repeat interval, which translates to requiring a large physical antenna aperture. These studies, as well as other implemented missions, have historically turned to deployable phased array antennas for the instrument aperture. However, while phased arrays offer excellent performance and a diverse range of operating modes, very large phased arrays tend to be prohibitively expensive for space applications.

The DESDynI concept is an L-band, polarimetric SAR instrument for repeat-pass interferometry, with a large physical aperture implemented as a deployable reflector fed by an array. This would afford an antenna with a high directivity (>40 dBi) and low areal mass density (<5 kg/m^2). This performance is superior to prior spaceborne SAR antenna systems. Arguably, the DESDynI approach is at a higher technology readiness level and would be more cost-effective than comparable future-oriented large-aperture phased array systems.

II. Antenna Architecture

The DESDynI concept would use an offset paraboloid antenna with an array feed at the focus, as shown in Fig. 1. A number of point designs have been evaluated for this system. Typical projected aperture diameter (D) has ranged from 6m to 15m, and focal length to diameter ratio (F/D) has ranged from 0.7 to 1. The feed is offset (H/D = -1/7.5) toward the reflector center and partially blocks the field of view. Feed-reflector and supporting structure interactions are accounted for when generating secondary patterns for the antenna system.

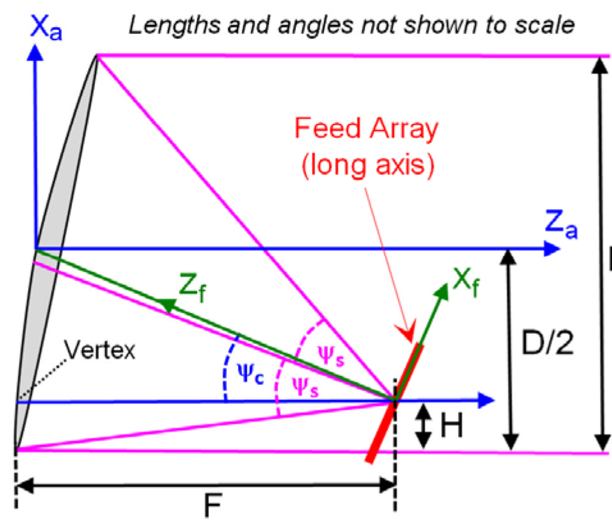

Figure 1. DESDynI antenna architecture.

III. Feed Architecture, Construction, and Modeling

The feed would comprise an Nx2 array of patch elements. Pairs of elements in azimuth (y_f-direction) would be fed by separate pairs of transmit/receive modules (TRMs) – one for each polarization (Fig. 2). This architecture would obviate the need for a high power polarization switch at the output of the TRM. On transmit, all patch element pairs would be excited simultaneously, producing a narrow pattern that under illuminates the reflector in elevation. This would result in a broad elevation (x_a-direction) beam in the secondary pattern producing a wide swath on the ground. On receive, the digitized outputs of the TRM receivers would be sequentially switched along the feed to time-sample (and combine) the reflected signal. This would effectively scan a series of narrow, digitally-formed beams in elevation, one for each pair of elements, across the broad secondary transmit pattern. This asymmetrical mode of radar operation is termed *SweepSAR*. The number of elements pairs in the feed has ranged from between 8 to 32 in various point designs considered so far, with current studies focusing on the smaller number in order to meet cost objectives.

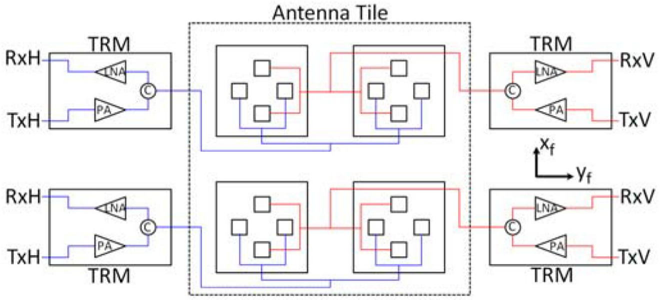

Figure 2. Feed array configuration showing sub-array of 2x2 elements and associated active analog components. Simplified TRM comprises: low noise amplifier (LNA), power amplifier (PA), and circulator (C).

The passive aperture architecture would use a common building block termed an *antenna tile*, delineated by the dotted line in Figure 2. The feed array would be formed by replicating antenna tiles (and groups of TRMs) in the x_f-direction. Antenna tiles represent a fabrication subassembly. They would comprise a sub-array of probe-fed patch elements and associated feed networks implemented in stripline. The proposed DESDynI L-band antenna tiles would be 2x2, 3x2 or 4x2 sub-arrays, depending on element spacing and the total number of elements. The configuration of antenna tiles is constrained by performance requirements and fabrication processes, which are discussed subsequently. The proposed DESDynI antenna tile borrows heavily from the tile developed for UAVSAR [2].

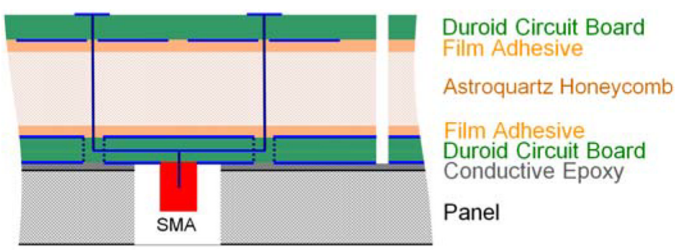

Figure 3. UAVSAR antenna tile stackup. DESDynI tile would be similar but with different panel attachment method.

Antenna tiles are constructed as a composite assembly of an Astroquartz honeycomb substrate sandwiched between two Duroid circuit boards (Fig. 3). The assembly is bonded together using film adhesive in a high temperature cure. Materials are chosen to have excellent RF performance and low coefficient of thermal expansion (CTE). The patch layer is etched on the lower surface of the upper circuit board, while the stripline passive feed network is implemented in the lower circuit board. The stripline circuit board is fabricated using a fusion bond process and the circuit traces are fenced with vias to ensure good isolation. Probe interconnects couple capacitively from the patch to the stripline feed. The coupling capacitors (etched on the top layer of the upper circuit board) resonate with the probe inductance to provide a good impedance match. The Astroquartz thickness is 18mm in the current point design to provide a bandwidth of 80 MHz.

In order to reduce fabrication costs and avail the fabrication of circuit boards to the widest range of vendors, tiles are designed to fit on a standard 18” x 24” (46cm x 61cm) Duroid panel. Typical element spacing ranges between 13cm and 23cm. Including tooling for both circuit board production and tile production, this constrains tile area to accommodate between 2x2 elements and 4x2 elements. Larger tiles tend to have disadvantages in terms of limited vendor options, increased potato chipping from CTE mismatch, and value lost in the event of non-reworkable fabrication error.

For the DESDynI concept, tiles are envisioned as being attached to a mechanical support structure using standoffs and fasteners. In the UAVSAR phased array aperture [2], tiles were bonded to an Aluminum honeycomb panel using conductive epoxy. This proved to be a difficult process to both develop and implement. However, the conductive epoxy layer does ensure good tile-to-tile continuity and eliminates the possibility of edge-currents (at tile-tile boundaries) that could cause grating lobes. The mechanically attached DESDynI tiles would require some other mechanism for ensuring that inter-tile edge currents would not be a problem.

Antenna sub-arrays, in a variety of configurations, are modeled using HFSS. The patterns from these simulations are then imported into GRASP as a tabulated feed in order to generate the secondary patterns of the array-fed reflector. GRASP has a built in circular patch element, but the patterns generated from this model do not include scattering in the back hemisphere. Ideally, the HFSS model would include the full Nx2 array of patch elements, but the generation of 2N pattern sets (one for each polarization) for such a model becomes time consuming, especially when iterating through a number of configurations. To this end, a simplified 1x2 model is used with linked boundary conditions on the faces normal to the long direction of the array, and radiation boundary conditions on the other faces. Compared with full array pattern sets, this model produces relatively accurate main beam patterns for the reflector antenna system at the cost of slightly reduced accuracy in far side lobes due to tile edge scattering. This performance degradation is acceptable for trade study purposes.

IV. Summary

This paper has provided an overview of the antenna feed for the proposed DESDynI array-fed reflector. The proposed feed architecture borrows heavily from a similar antenna developed for UAVSAR, and would afford a flexible, low-cost, and low-risk approach to the development of the instrument antenna.

V. Acknowledgement

The research described in this paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

VI. References

[1] N. F. Chamberlain, et al, “The DESDynI Synthetic Aperture Radar Array-Fed Reflector Antenna”, IEEE Phased Array Conference, Boston MA, Nov 2010.

[2] N. F. Chamberlain, et al, “The UAVSAR Phased Array Aperture”, IEEE Aerospace Conference, Big Sky MT, March 2006.